SAN ANTONIO

SIGGRAPH 2002

Interactive Multiresolution Hair Modeling and Editing

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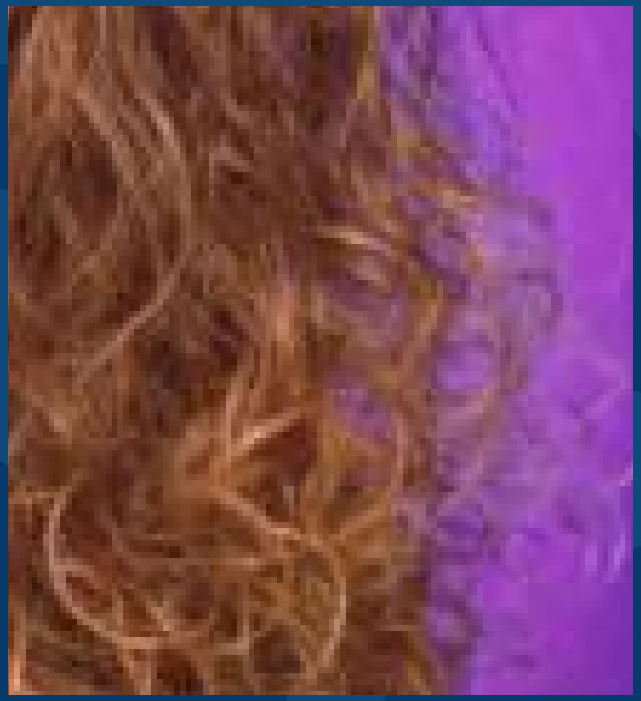
Problem statement



Photograph courtesy by www.hairboutique.com

Modeling human hair

- Complex discontinuous volume
- Clusters and curliness
- Virtually any shape is possible
- Number of hair strands (100K to 200K)

Our Goal

Interactive system for modeling complex human hair in a reasonable amount of time (< 1 hour)

- Efficient sculpting of volumetric hair model
- Interactive rendering of arbitrary explicit hair models

Our Goal

Our model

Photograph courtesy by www.hairboutique.com

Presentation Overview

- Related work
- Multiresolution hair representation
- Hair editing operations
- Interactive hair rendering
- Results
- Discussion and conclusion

Related Work

- **Strand based approach**

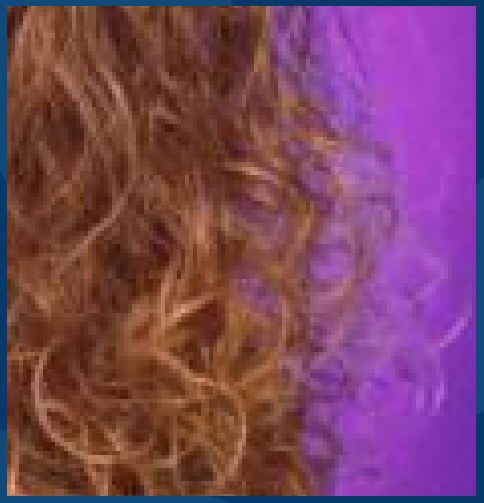
  [Anjyo et al., SIGGRAPH 1991; Rosenblum et al., JVCA 1991; Lee and Ko, GM2001; Hadap and Thalmann 2001, EG 2001]
- **Key hair (interpolation)**

  [Watanabe and Suenaga CG&A 1992; Daldegan et al., EG 1993; Chen et al., VC1999; Chang et al., SCA2002]

Related Work

- **Fluid flow and vector field**
  [Hadap and Thalmann, EGCAS 2000; Yu, PG 2001]
- **Short hair/fur**
  [Kajiya and Kay, SIGGRAPH 1989; Lengyel et al., I3D 2001]
- **Discontinuous wisp**
  [Xu and Yang, CG&A 2001; Plante et al., EGCAS 2001; 'Shrek']
- **Automatic reconstruction**
  [Grabli et al., GI 2002]

Common Problems


Long hairs cluster, split, and curl away

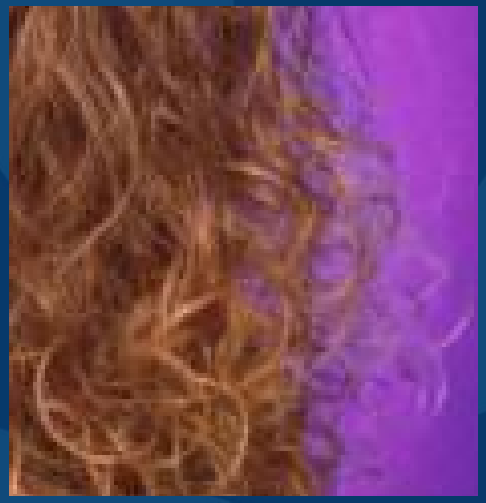
→Complex hairstyles with extreme discontinuity are difficult to model

Observation



Clustering effects occur at multiple scales

Observation


Clustering effects occur at multiple scales

→Multiresolution approach for hair modeling

Our Approach

- Hair cluster shape modeling with generalized cylinders (GC)
- Subdivision and hierarchical hair structure
- Multiresolution editing tools
- Copy and paste operations
- Capture structural aspects of volumetric hairstyles

Scalp Surface

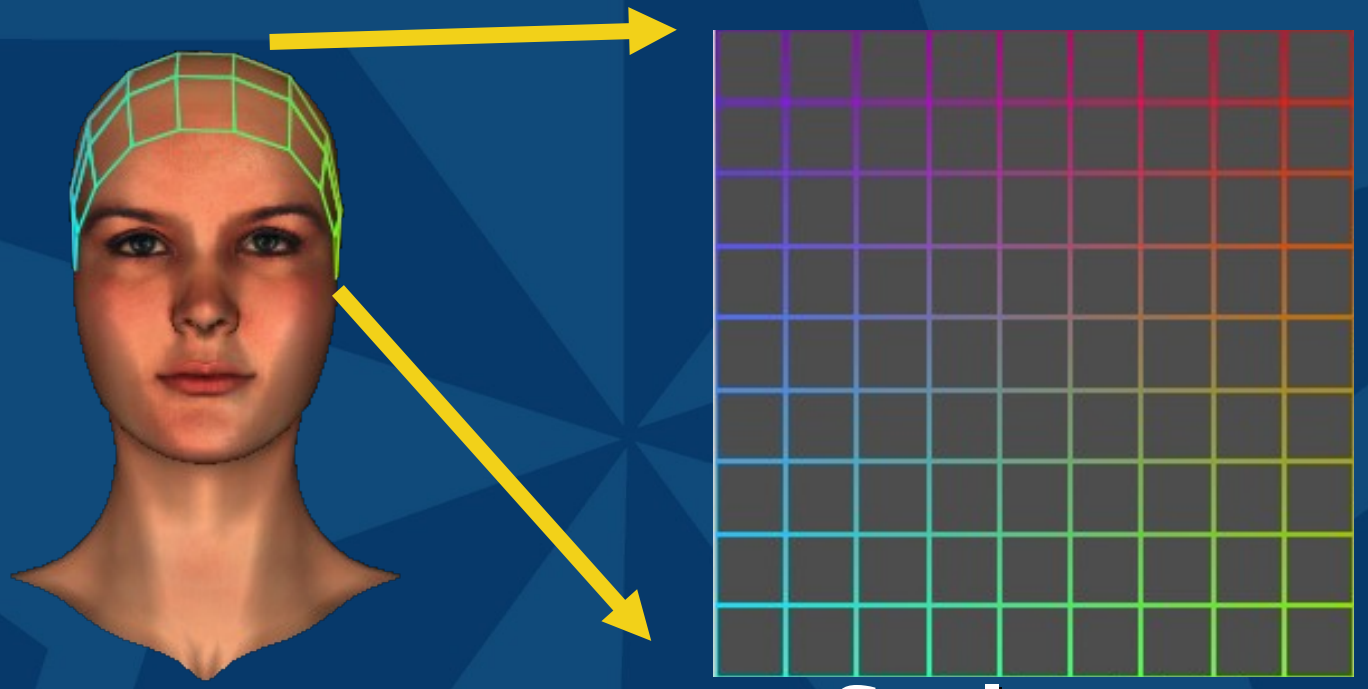
Scalp Surface

- Parametric surface

  $S = P(u,v)$

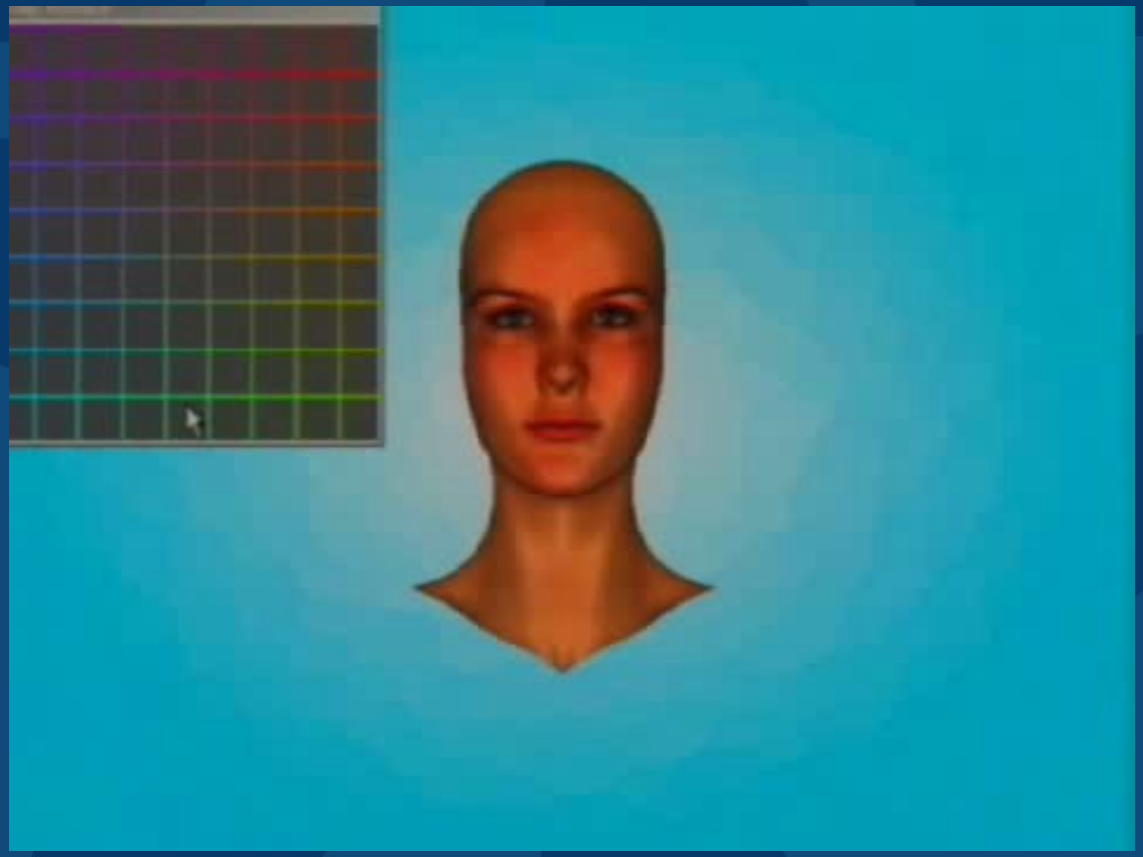
- Defines the region of hair growth

Scalp Surface



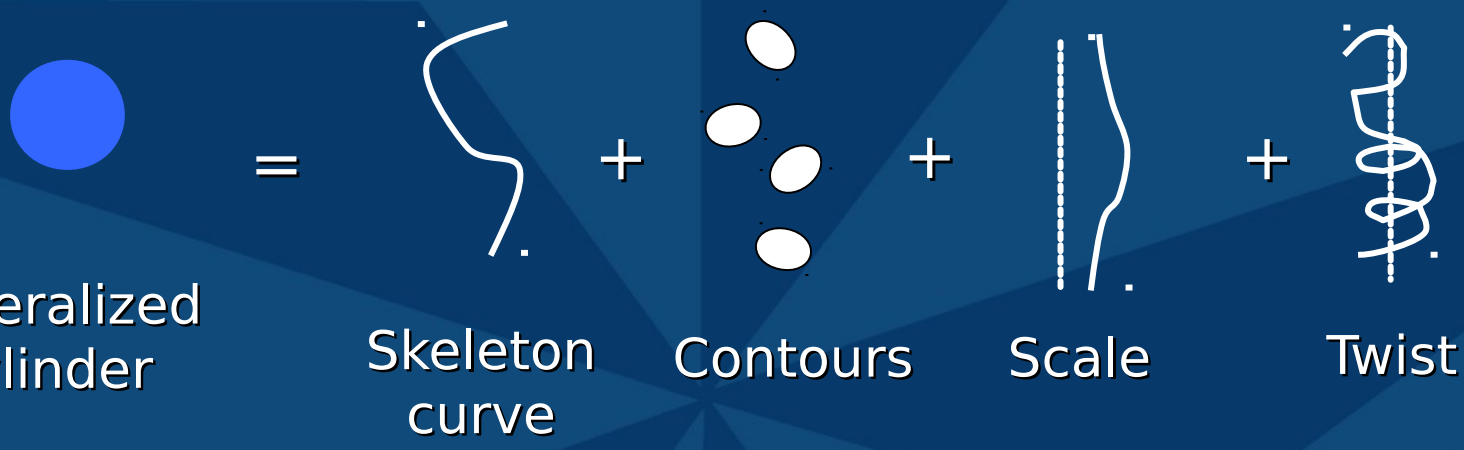
Scalp space editor

Scalp Surface



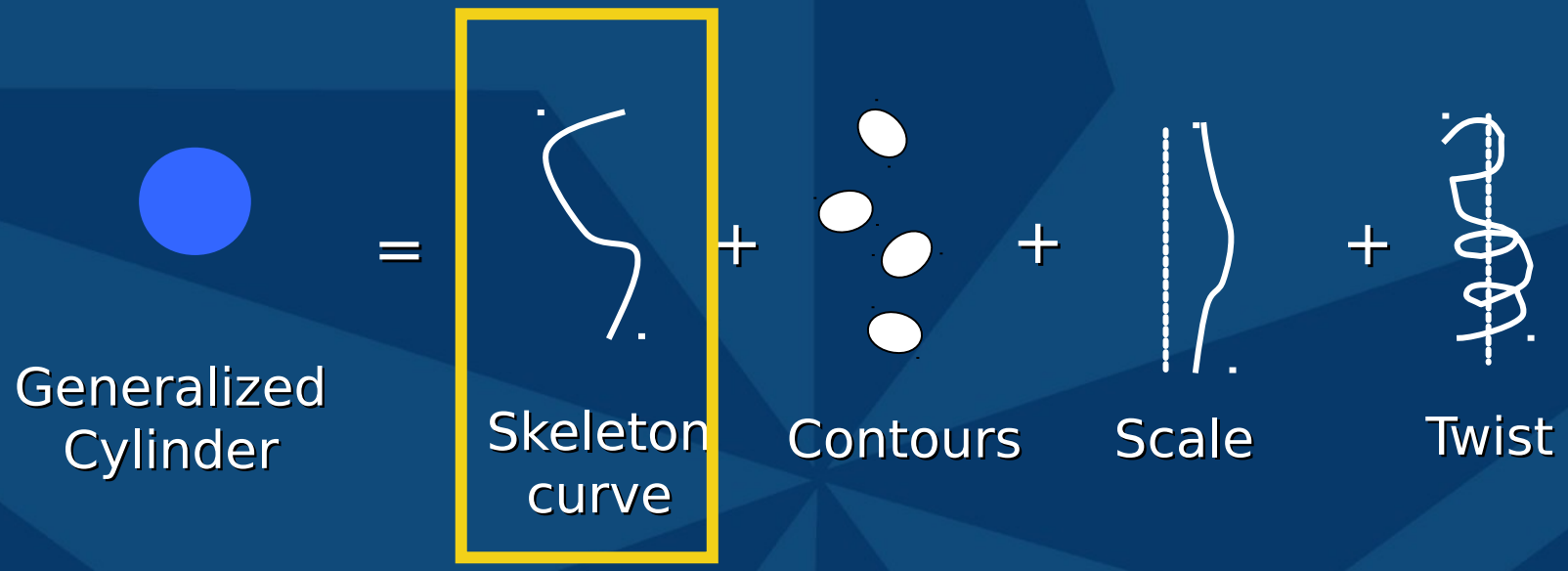
Atlas for hair cluster positioning

Generalized Cylinder (GC)



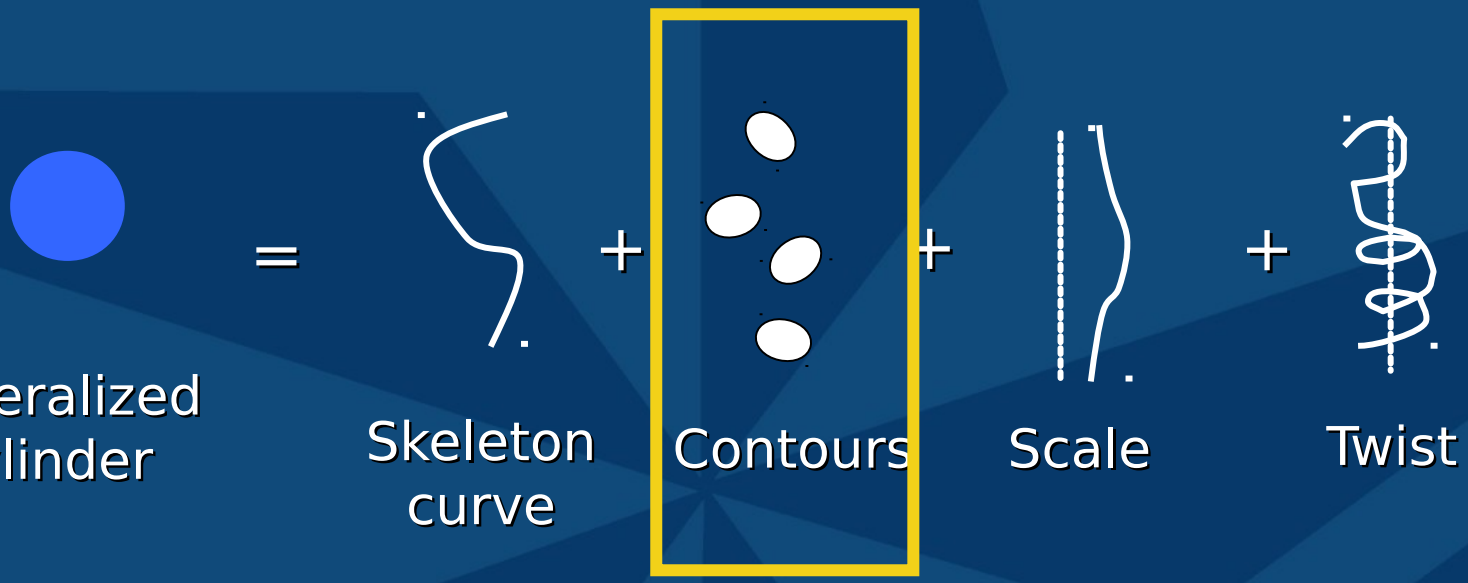
$$V(r,\theta,t) = C(t) + rR(\theta,t)\left\{\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right\}$$

Generalized Cylinder (GC)



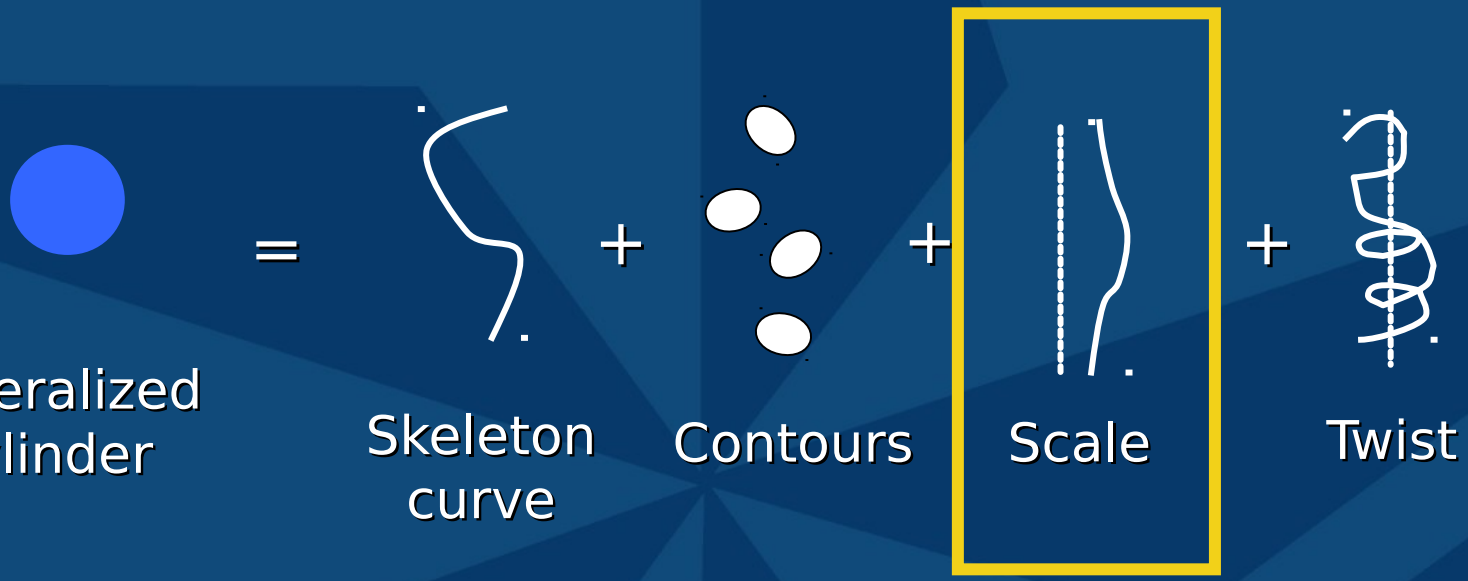
$$V(r,\theta,t) = C(t) + rR(\theta,t)\left\{\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right\}$$

Generalized Cylinder (GC)



$$V(r,\theta,t) = C(t) + rR(\theta,t)\left\{\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right\}$$

Generalized Cylinder (GC)

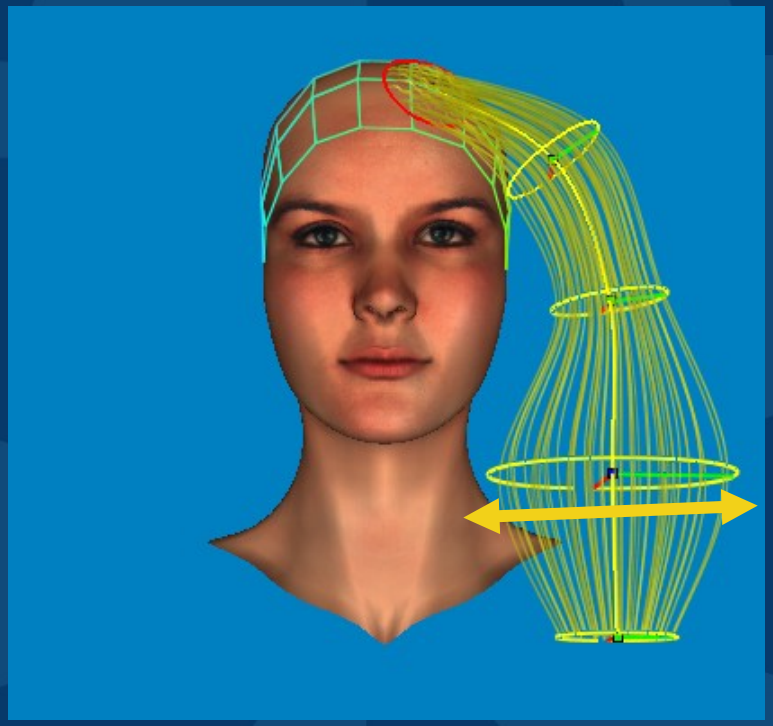


$$V(r,\theta,t) = C(t) + rR(\theta,t)\left\{\cos\hat{\theta}\,S_N(t)N(t) + \sin\hat{\theta}\,S_B(t)B(t)\right\}$$

Generalized Cylinder (GC)

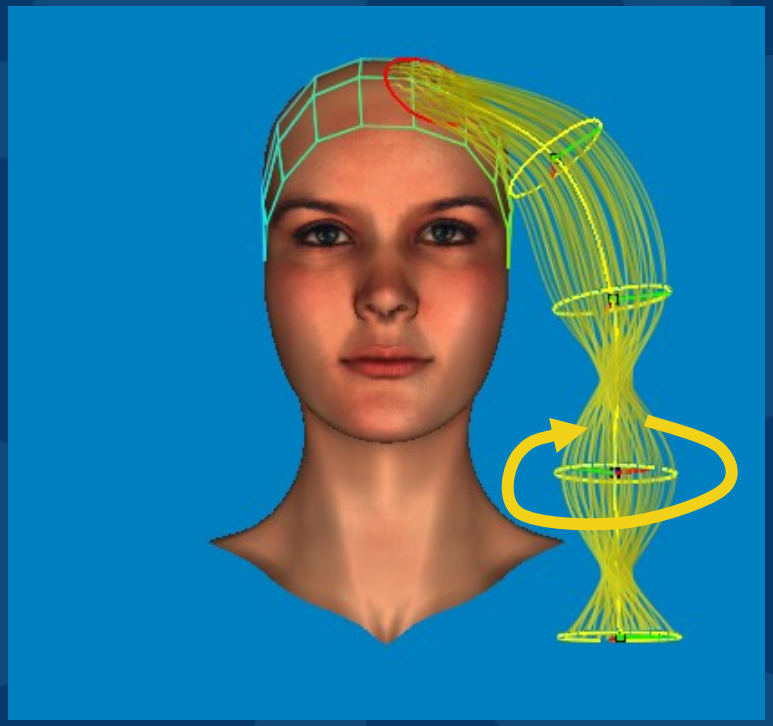
$$V(r,\theta,t) = C(t) + rR(\theta,t)\left\{\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right\}$$

Scale Change



$$V(r,\theta,t) = C(t) + rR(\theta,t)\left[\cos(\hat{\theta})\,S_N(t)\,N(t) + \sin(\hat{\theta})\,S_B(t)\,B(t)\right]$$

Twist Change



$$V(r,\theta,t) = C(t) + rR(\theta,t)\left[\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right]$$

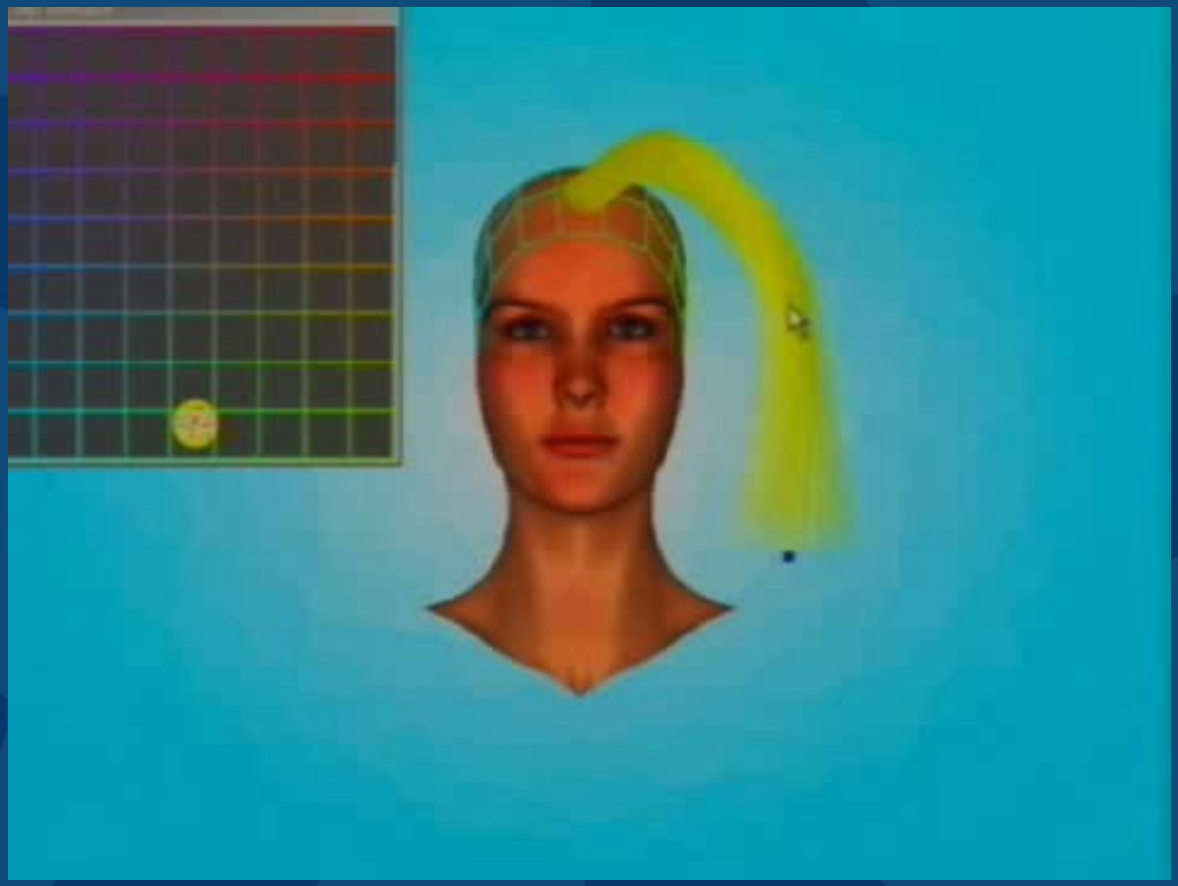
Adding Details

- A single generalized cylinder (GC) is limited by a few parameters
- Simply adding more GCs results in too many controls

Subdivision

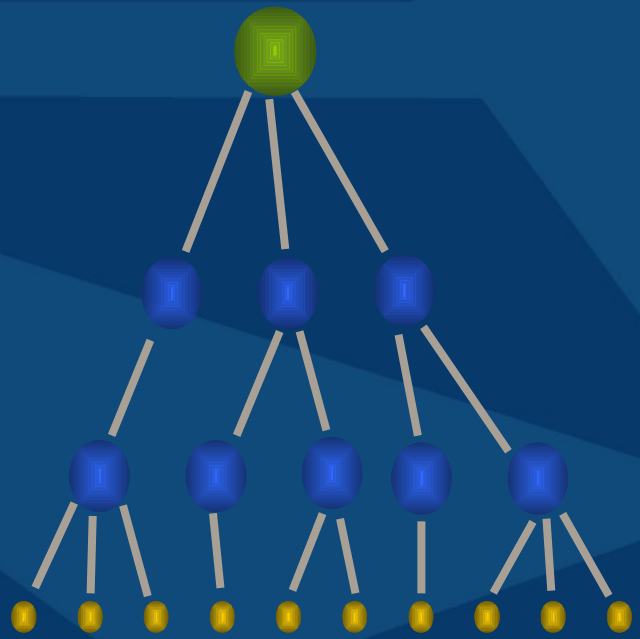
- Subdivide a parent GC into several smaller child GCs
- Hierarchical control over the hair model
- Editing a child GC changes the shape of hair strands
- Editing a parent GC affects child GCs as well as hair strands

Subdivision



Interactive Multiresolution Hair Modeling and Editing

Hair Tree



A hair model

Generalized cylinder

Hair strand

- Subdivision allows more refined controls to the hair model → down to a hair strand

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation

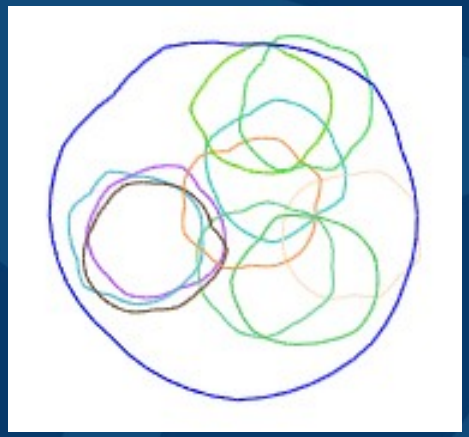
Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation

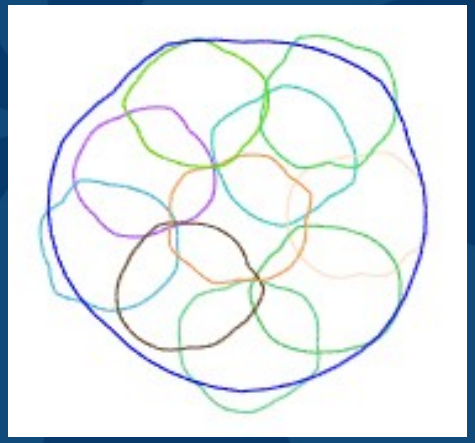
$$V(r,\theta,t) = C(t) + rR(\theta,t)\left[\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right]$$

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation



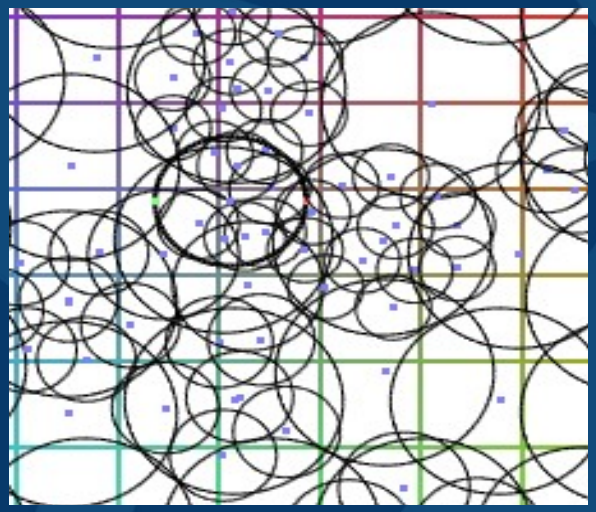
Random Positioning



Position Relaxation

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation

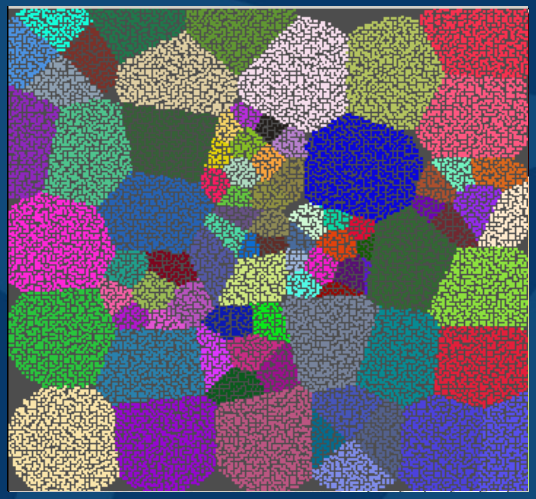


Overlaps and holes

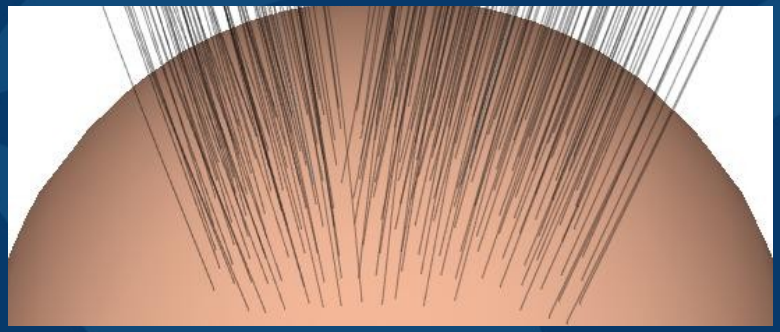
Uneven hair density

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation



Hair assignment



Consistent hair density

Multiresolution Editing

Interactive Multiresolution Hair Modeling and Editing

Multiresolution Editing

- **Bind**

  When a GC is selected for edit, its descendants are attached to the GC

- **Update**

  During editing, the children GCs are updated using GC equation of the parent

Multiresolution Editing

- **Bind: P = V(r,θ,t)**

  (r,θ,t)=V^{-1}(P)

V(r,θ,t) → V'(r,θ,t)

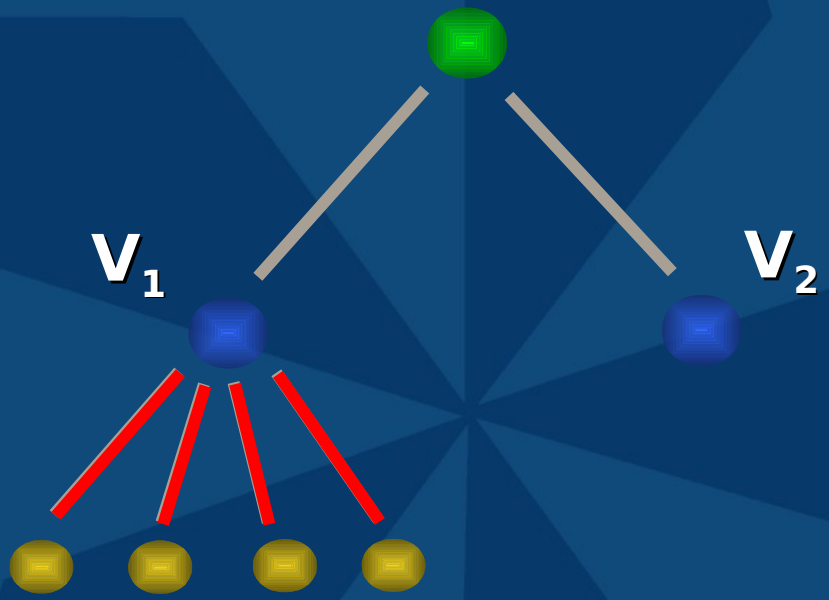
- **Update: P' = V'(r,θ,t)**

$$V(r,\theta,t) = C(t) + rR(\theta,t)\left\{\cos(\hat{\theta})S_N(t)N(t) + \sin(\hat{\theta})S_B(t)B(t)\right\}$$

Copy and Paste

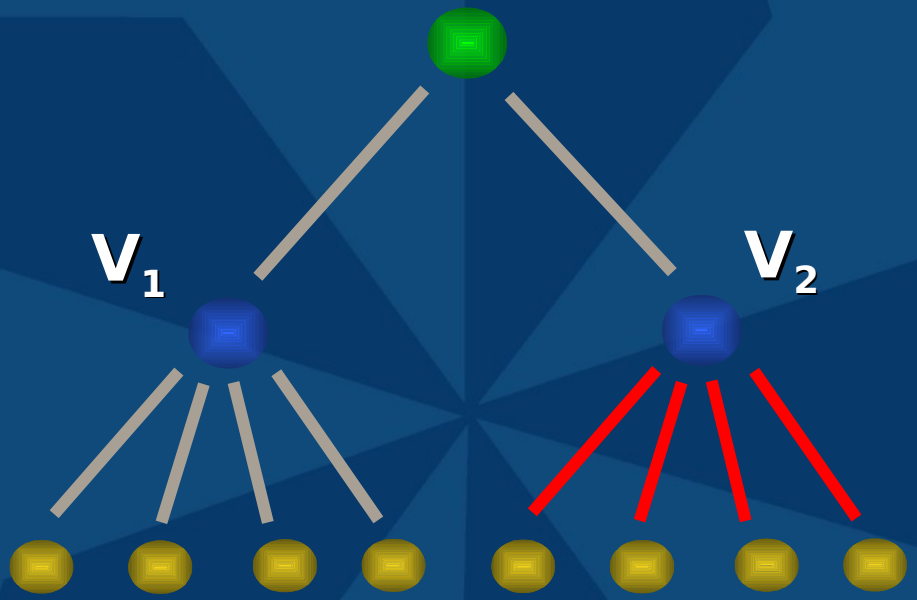
Transfer a *style* from one cluster to another

Copy and Paste



$$(r,\theta,t)=V_1^{-1}(P)$$

Copy and Paste



$$P = V_2(r,\theta,t)$$

Copy and Paste

Example

Global hair shape modeling with GCs

Example

Subdivision and local editing

Example

Copy and paste

Example

Multiresolution editing and refinement

Example

Example

Top level
(30 GCs)

2nd level
(177 GCs)

3rd level
(840 GCs)

Interactive Rendering

- Explicit geometry
- Any hair renderer that handles arbitrary explicit hair models could be used
- Instant feedback for WYSIWYG hair modeling
- Integrated rendering system with OpenGL hardware
- Each hair strand drawn as polyline

Interactive Rendering

- Self-shadows
- Anti-aliasing

→ Interactive visualization of complex hair geometry

Self-shadows

- Crucial for volumetric hair

No shadows

With shadows

Self-shadows

- Crucial for volumetric hair

Self-shadows

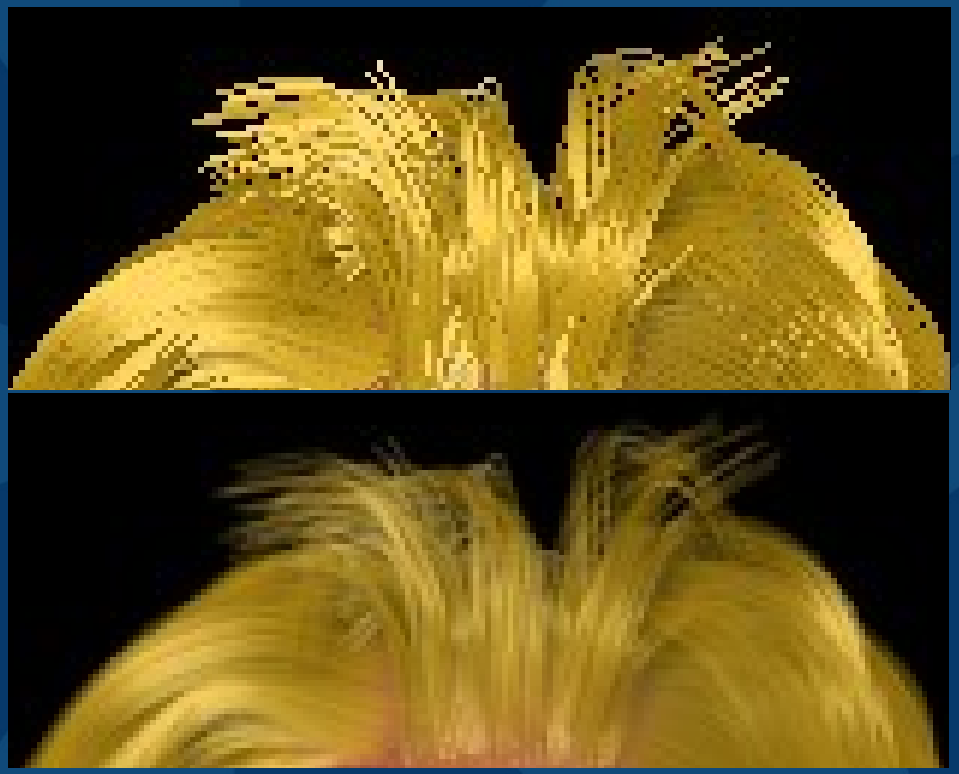
- Opacity shadow maps

  [Kim and Neumann, EGRW 2001]
- Scalable approximation for volumetric shadows
- Cached shadows for interactive visualization

Antialiasing

Without Antialiasing

With Antialiasing



Antialiasing

Results

Interactive Multiresolution Hair Modeling and Editing

Results

Results

Results

Results

Results

Conclusion

- **Multiresolution hair modeling framework**
- **Interactive hair rendering**

Extensions

- High level tools for global shape modeling
- Hairstyle database
- Use other modeling systems as front-end and ours as back-end
- Fitting and stitching of GCs
- Model transfer between different head meshes

How to animate it?

- Kinematic control for top-level clusters
- Strand-based animation techniques
- Fitting GCs for key hair approach
- Multiresolution framework for hair animation (dynamic hair tree)
- Hair-hair interaction algorithms for complex hair models

Acknowledgements

- USC Annenberg Center
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- Junyong Noh, Doug Fidaleo, Clint Chua
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- Marianne LaFrance
- Sean Mausch, Laehyun Kim
- All the colleagues at USC CGIT laboratory

Level of Detail

High complexity model 1.2M lines
20000 strands, 60 lines / strand, a = 0.3

Low complexity model (100K lines)
5000 strands, 20 lines / strand, a = 1.0

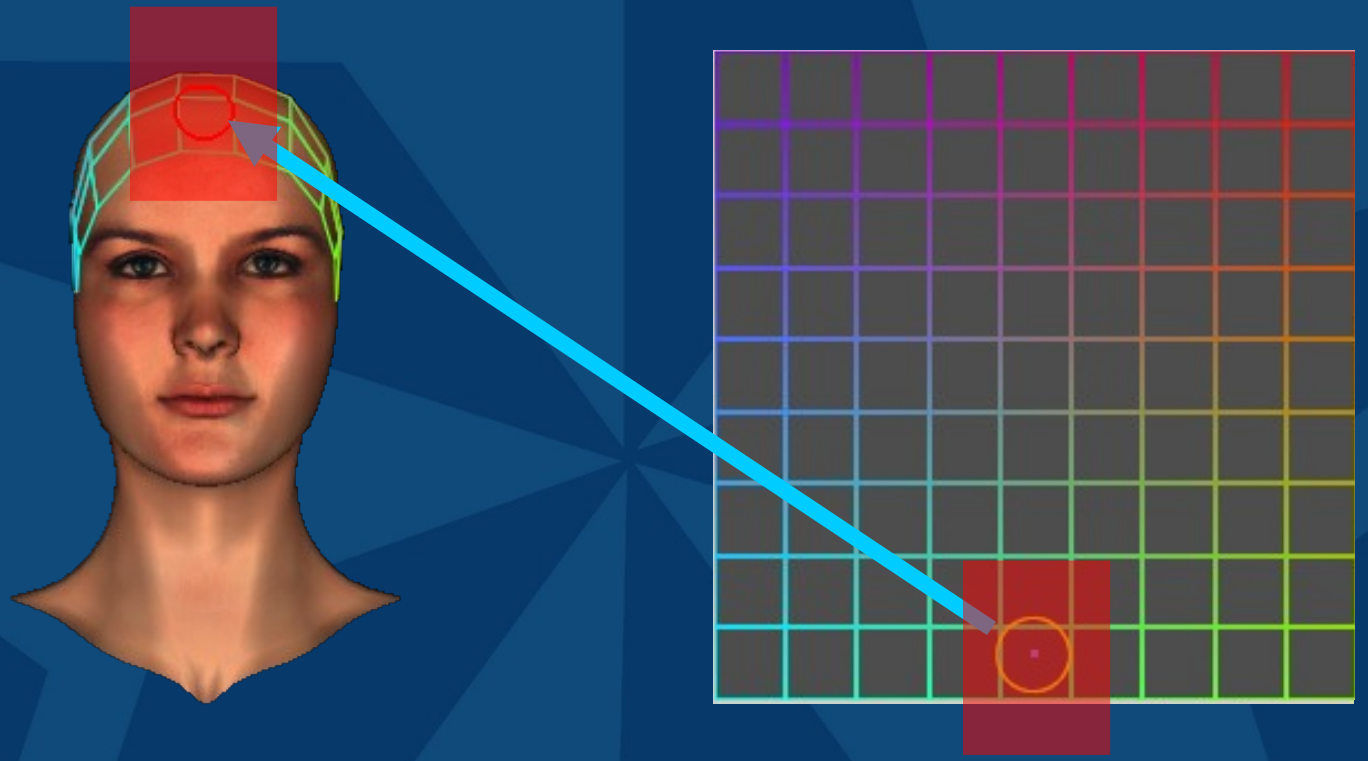
Level of Detail

High complexity model (1.2M lines)

Low complexity model (100K lines)

Results (video)

Scalp Surface



Atlas for hair cluster positioning